Altered Viscosity of Nasal Secretions in Postnasal Drip

Bucher, Sarina ; Schmid-Grendelmeier, Peter ; Soyka, Michael B

Abstract: BACKGROUND: Postnasal Drip (PND) is a common symptom associated with upper respiratory tract disorders. It occurs without other symptoms or combined with chronic rhinosinusitis (CRS). However, the pathophysiology of PND is debated to this day and an objective definition of PND has not been established. Therefore we aimed to elucidate whether the viscosity and volume of nasal secretions as well as the mucociliary clearance and sensitivity of the nasopharynx, or atopy could play a role in the pathophysiology of PND. METHODS: A prospective case-control study of 30 patients - 15 PND and 15 healthy subjects - was conducted. The viscosity and volume of nasal secretions, the nasopharyngeal sensitivity, the mucociliary clearance, and allergic sensitisation using a skin prick test (SPT) were assessed in all subjects. RESULTS: Viscosity of nasal secretions in PND patients was significantly increased compared to healthy subjects. Two follow-up measurements in symptom-free intervals showed reversibility of increased viscosity. Analysis of nasopharyngeal sensitivity showed significant reductions in PND patients. Furthermore, mucociliary clearance seems to be prolonged in PND patients. The volume of nasal secretions and the atopy screening showed no significant differences in PND compared to healthy individuals. CONCLUSION: Increased viscosity seems to play a relevant role in the pathophysiology of PND. Additionally, delayed mucociliary clearance as well as hyposensitivity of the nasopharynx may be further components. Earlier concepts of PND, regarding an increased volume of secretions and atopy, do not seem to hold true since our analyses showed no significant difference between cases and controls.

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Altered Viscosity of Nasal Secretions in Postnasal Drip

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CONFLICT OF INTEREST

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ABBREVIATION LIST

CRS	Chronic Rhinosinusitis
HPMC	Hydroxypropyl Methylcellulose
PND	Postnasal Drip
SPT	Skin Prick Test
STT	Saccharine Transit Time

ABSTRACT

Background: *Postnasal Drip (PND) is a common symptom associated with upper respiratory tract disorders. It occurs without other symptoms or combined with chronic rhinosinusitis (CRS). However, the pathophysiology of PND is debated to this day and an objective definition of PND has not been established. Therefore we aimed to elucidate whether the viscosity and volume of nasal secretions as well as the mucociliary clearance and sensitivity of the nasopharynx, or atopy could play a role in the pathophysiology of PND.*

Methods: *A prospective case-control study of 30 patients – 15 PND and 15 healthy subjects – was conducted. The viscosity and volume of nasal secretions, the nasopharyngeal sensitivity, the mucociliary clearance, and allergic sensitisation using a skin prick test (SPT) were assessed in all subjects.*

Results: *Viscosity of nasal secretions in PND patients was significantly increased compared to healthy subjects. Two follow-up measurements in symptom-free intervals showed reversibility of increased viscosity. Analysis of nasopharyngeal sensitivity showed significant reductions in PND patients. Furthermore, mucociliary clearance seems to be prolonged in PND patients. The volume of nasal secretions and the atopy screening showed no significant differences in PND compared to healthy individuals.*

Conclusion: *Increased viscosity seems to play a relevant role in the pathophysiology of PND. Additionally, delayed mucociliary clearance as well as hyposensitivity of the nasopharynx may be further components. Earlier concepts of PND, regarding an increased volume of secretions and atopy, do not seem to hold true since our analyses showed no significant difference between cases and controls.*

KEY WORDS

postnasal drip, secretion, viscosity, mucociliary clearance, sensitivity

INTRODUCTION

Postnasal Drip (PND) is an imprecise diagnosis. Its pathophysiology, as first described by Dobell in 1866 [1], is debated to this day. Nevertheless, PND is a common symptom associated with upper respiratory tract disorders. Diagnosis of PND basically relies on the patient's reporting of something dripping down into the throat, foreign body sensation in the throat, chronic cough, nasal discharge, or frequent throat clearing. Furthermore, on examination of the naso- or oropharynges the presence of mucoid or mucopurulent secretions is often seen. PND occurs without other symptoms or combined with other upper respiratory tract disorders. However, its pathophysiology is not definitely clarified yet. The concept of an increased fluid volume running from the posterior nasal choanae into the posterior naso- or oropharynx seems to be too simplified. As Rimmer and colleagues postulated, the pathophysiology of PND could also be associated with altered viscosity of nasal secretions or sensory dysfunction of the nasopharynx due to mucosal inflammation but no evidence was provided [2]. The viscosity and elasticity are the fundamental rheological properties of nasal mucus [3], and are important determinants of transportability of mucus in the mucociliary system [4,5]. Viscosity describes the capacity to respond to deforming forces by flowing, whereas elasticity refers to the ability to resist deformation by storing energy and recoiling. Since we focused on viscosity of nasal secretions other rheological terms such as complex modulus are not further discussed.

Nasal glands and goblet cells are mainly responsible for the production of nasal secretion, while there is also a contribution from plasma exudation in the inflammatory state [2]. Nasal mucus contains 95% water, 2.5% glycoproteins, 1-2% electrolytes and other proteins such as lysozyme, lactoferrin, and complement [6]. Further contents may be tears as well as condensed exhaled water – the relative contributions of each are unknown [2]. The viscosity of nasal secretions results from factors including the degree of hydration and the extent of cross linkages of mucus glycoproteins such as fucose and sialic acid.

An additional hypothesis is that delayed mucociliary clearance, inability to produce proper nasal secretions, as well as atopic sensitization are jointly responsible for the sensation of PND. Since viscosity and mucociliary clearance negatively correlates with each other [7,8], this hypothesis seems to be plausible. We therefore postulated in our hypothesis that an altered viscosity of nasal secretions, a changed sensitivity – in line with a sensory dysfunction – and a prolonged mucociliary clearance result in the clinical symptoms of PND.

The aims of this study were fivefold: to assess whether the viscosity and volume of nasal secretions, the mucociliary clearance and sensitivity of the nasopharynx, as well as the allergic sensitisation are different in PND patients compared to our matched control group.

MATERIALS AND METHODS

Ethics

Informed consent was obtained from every patient, and this study was approved by Swiss Ethics Committees on research involving humans (ID: KEK 2018-00603). It was conducted in compliance with formalities of the independent ethical commission, the current Helsinki-Declaration as well as the Swiss law.

Study Design and Population

This monocentric prospective case-control study of patients with PND was conducted at the Department of Otorhinolaryngology, Head and Neck Surgery, University Hospital Zurich. The study population consisted of 15 patients with typical symptoms of PND. All of these patients were required to report fluid dripping down into their throat in addition to at least two other typical PND symptoms such as foreign body sensation in the throat, chronic cough, nasal discharge, or frequent throat clearing. These symptoms have also been the reason they were seeking medical assistance for. Only chronic PND patients were recruited from outpatient clinics at the University Hospital Zurich and examined by the same trained examiner (S.B). To be eligible, participants were required to be aged between 18 and 70 years and able to give written consent. Exclusion criteria for all participants were current nasal medication, neoplasia of the naso- or oropharynx as well as acute states of PND.

The control group comprised 15 patients without any nasal symptoms especially without any PND symptoms as described above. It was matched for age and sex (Table 1).

All patients were asked about their medication and its potential influence on nasal secretions or one of the other parameters analyzed was evaluated. Therefore, all patients withheld oral cortisone for at least two weeks and intranasal cortisone as well as antihistamines for 48 hours. Comorbidities of all patients were recorded and specifically assessed for diseases influencing nasal secretions, mucociliary clearance or sensitivity in the nasopharynx such as cystic fibrosis or primary ciliary dysfunction. If patients underwent functional lung tests, results were noted. Since all our patients were adults, chloride sweat tests were not regularly performed.

Data Collection

Nasal Mucociliary Clearance

Mucociliary clearance of the nasopharynx was examined in all individuals using the saccharine transit test (STT) [9]. The STT measures the elapsed time between saccharine deposition 2 cm inside the non-obstructed nostril and the first perception of a sweet taste in the mouth or oropharynx. Patients were evaluated under standardized conditions with ambient temperature at 21-23 °C and 58-67% relative humidity. The subjects remained in a seated position throughout the examination. Patients were instructed to maintain normal ventilation and to avoid sniffing, coughing, sneezing, deep breaths or talking during the test. A normal value for a healthy adult is described as less than 12 minutes [9–12]. In case the STT exceeded 20 minutes, the test was stopped and a specific note in the case report form was taken.

Skin Prick Test

SPT were performed with a commercial standard protocol (house dust mite such as *Dermatophagoides pteronyssinus* and *Dermatophagoides farinae*, cockroach, dog hair, cat epithelium, horsehair, *Alternaria alternata, Penicillium penicillium, Candida albicans, Cladosporium herbarum*, grass-mix, mugwort-, birch-, alder-, ash-, hazel- and rye pollen, and ragweed) (ALK-Abelló). Solutions of 0.9% saline and 0.01% histamine hydrochloride (ALK-Abelló) served as negative and positive control, respectively. SPTs were conducted in double on the volar forearm applied in opposite directions and evaluated after 20 minutes, as described [13]. Reactions were considered positive when a mean wheal diameter of >4 mm was seen.

Collection and Viscosity of Mucus

The nasal mucus was collected by using one half of a 15 mm thin Merocel (Medtronic Xomed, Jacksonville, Fl. USA) for each nostril. The Merocels were placed in the nasal cavity for 20 minutes. Afterwards, they were centrifuged on 4500 rotations per minute at 25°C for 15 minutes. To determine the volume of nasal mucus, standardized 100 µl- and 10 µl-pipettes were used. Analyses of viscosity of nasal mucus were conducted by a plate rheometer (the Modular Compact Rheometer MCR 102, Anton Paar, Graz, Austria) with a CP25-1 measure plate at 37 °C. A 30 µl aliquot of the patient's nasal mucus was placed on the rheometer plate to allow equilibration for 30 seconds at 37 °C, ensuring nearly in vivo conditions. A range of oscillatory frequencies – shear rates between 0.1 and 10'000 γ – was applied to the samples at a constant strain to measure viscosity. Viscosity was recorded at 27 different measuring points and determined at 1 rad/s as well as 100 rad/s for each

sample. All measurements were directly conducted after mucus collection to minimize alterations in rheological characteristics.

Sensitivity of the Nasopharynx

The sensitivity of the nasopharynx was examined without local anaesthesia using a rigid 2 mm nasal endoscope (Karl Storz, Tuttlingen, Germany) coupled to an adapted 0.9 mm extension set normally used for arterial blood pressure measurements (Codan, Lensahn, Germany). This measuring instrument is illustrated in Figure 5. The extension set was connected to one of the apertures of a three-way cock. The second opening was connected to a Foley catheter (16 Charière, Teleflex®, Athlone, Ireland). A syringe was connected to the third opening for the air supply. First, defined amounts of air (50 ml, 40 ml, 35 ml, 30 ml, 25 ml, 20 ml, 15 ml, 10 ml, 5 ml, 3 ml, 2 ml) were filled into the Foley catheter. For each amount of air, the three-way cock was then opened in a way, that the defined amount of air was flowing from the Foley catheter only into the extension set and thereby to the end of the endoscope, which was placed 1cm in front of the nasopharynx. Using this method, a constant and defined flow of air could be ensured. Thereby, the smallest air volume, which surely could be sensed as an air puff, and clearly discriminated from the sensation of cold, was detected.

Statistical Analyses

Statistical analysis was performed using SPSS software version 25.0 (IBM, Armonk, NY, USA), and a two-sided P value of < 0.05 was considered significant. The normality of distribution was checked using the Kolmogorov-Smirnov test. The Student t test was used to compare continuous variables, whereas Pearson x^2 tests were performed for categorical data. For non-normally distributed continuous variables, a Mann-Whitney U test was used. Data are presented as medians ± SD.

RESULTS

In total 30 patients – 15 PND and 15 healthy subjects – were assessed. The male/female ratio of the study population (n = 30) was 12/18 and the average age was 38.9 ± 15.0 years. Four patients with CRS and two with not active recurrent acute rhinosinusitis were included in our study population. Allergic rhinitis was seasonal and, apart from potentially associated PND symptoms, not active during examination in all patients assessed. Neither cystic fibrosis nor primary ciliary dysfunction were recorded in our study population. Furthermore, all patients undergoing functional lung tests showed no pulmonary impairment. Further demographic information is presented in Table 1. Parameters of interest could be obtained in all patients. Two STTs were not evaluable due to sniffing of the nose, despite exact instructions.

Analyses of viscosity of nasal secretions at 1 rad/s as well as 100 rad/s showed significant differences in PND subjects compared to the control group ($p < 0.001$). Elevated viscosity was observed in 99.3% of PND patients. The median viscosity in PND patients was 8.41 ± 12.37 Pas at 1 rad/s or 0.11 ± 0.12 Pas at 100 rad/s and in controls 0.23 ± 0.75 Pas at 1 rad/s or 0.01 ± 0.02 Pas at 100 rad/s, respectively. Figure 1 and 2 demonstrates a more than ten times higher median of viscosity in PND subjects. Except for one, all of the other CRS patients clearly showed higher viscosity compared to non-CRS PND patients. Comparing the median viscosity, excluding PND patients with CRS, the PND median is still seven times higher compared to the control group (PND: 3.55 ± 3.93 Pas at 1 rad/s and 0.07 ± 0.04 Pas at 100 rad/s vs. Control: 0.23 ± 0.75 Pas at 1 rad/s and 0.01 ± 0.02 Pas at 100 rad/s). Two patients spontaneously reported improving PND symptoms. Therefore, we decided to retest these two individuals during an interval of decreasing or no symptoms. Follow-up measurements of viscosity in symptom-free episodes, one month after first examinations, showed similar values to healthy subjects (0.16 and 0.74 Pas at 1 rad/s and 0.003 and 0.01 Pas at 100 rad/s).

The STT in PND patients was significantly prolonged compared to controls ($p = 0.008$). The median in PND was 17.0 ± 4.2 min whereas it was 11.1 ± 4.7 min in healthy individuals. Figure 3 depicts a delayed mucociliary clearance in 76.92% (11/13) of PND patients.

The median air volume for an air puff sensation was 40 ± 19.0 ml in PND and 5 ± 11.8 ml in control subjects, which depicts significant differences in the nasopharyngeal sensitivity in PND patients compared to healthy individuals ($p = 0.002$) (Figure 4). In 60% of PND patients a hyposensitivity – defined as air volumes ≥35 ml for an air puff sensation – could be found.

The SPT displayed atopy in 25 patients (n = 30, 83.3%), 14 in the PND and 11 in the control group. No significant difference in atopy screening between cases and controls could be found (p = 0.367).

The volume of nasal secretions was not increased in PND patients (p = 0.061). A trend for reduced volumes of nasal secretions in PND patients compared to healthy individuals could be seen, as the median volume of nasal secretion was 120 ± 253.2 µl in PND patients and 340 ± 265.4 µl in controls.

DISCUSSION

This study provides three important new findings concerning the pathophysiology of PND. First, the viscosity of nasal secretions is significantly higher in PND patients compared to a matched control group. Second, the mucociliary clearance towards the nasopharynx is decreased. Third, patients with PND showed reduced nasopharyngeal sensitivity.

Viscosity was increased in 99.3% and mucociliary clearance was found to be delayed in 76.9% of PND patients. This has – to the best of our knowledge – never been demonstrated so far. Our findings disagree with Rimmer and colleagues' hypothesis concerning mucosal rheology not being relevant in the pathophysiology of PND [(2)]. We can clearly object their assumptions with direct evidence. The viscosity of nasal secretions under normal conditions is not well studied due to difficulties in obtaining adequate sample volumes. Hence most data are derived from samples obtained after provocation (methacholine, histamine, allergen), which could lead to differences in results [(14)]. However, the rheological characteristics of unprovoked nasal secretions in some disease states have already been reported [(6,7)]. Unfortunately, nasal secretions were not investigated under normal conditions or in PND patients. Nevertheless, they also encountered the problem of not being able to gather enough mucus from nasal cavities under unprovoked conditions in some disease states [(6)]. Therefore, we used one half of a 15 mm thin Merocel – ensuring an almost unprovoked collection of nasal mucus – for appropriate analyses. In their work, a double-capillary type viscometer was used [(6)]. Due to the advantage of changing shear rates over a wide range from 0.1 till 10'000 γ, allowing more precise measurements [(7)], we have chosen a plate type rheometer for our analyses. There are some disease states, e.g. CRS, non-allergic and allergic rhinitis as well as common cold, which result in an increased viscosity of nasal secretions [(6)]. Patients suffering from the above mentioned diseases were analyzed in detail. In our study population, four patients suffered from CRS. Allergic rhinitis was seasonal and, apart from potentially associated PND symptoms, not active during examination in all patients assessed. Since 33.3% of the controls also showed atopy for house dust mites, it is unlikely that atopy itself is largely relevant for PND symptoms. Except for one, all of the other CRS patients clearly showed higher viscosity compared to non-CRS PND patients. Comparing the median viscosity, excluding PND patients with CRS, at both 1 rad/s as well as 100 rad/s, the PND median is still seven times higher compared to the control group. As already described by others, viscosity of respiratory mucus can be altered by many factors, such as the degree of hydration, pH, the electrolyte concentration, types and quantity of mucins present, degree of its cross linking, alterations in electrostatic interactions among mucins, as well as polymer length, and the presence of extracellular material [(15)]. The percentage of solids was also found to correlate with increased viscosity and elasticity [(16)]. However, loss of hydration, as already described for rhinitis

patients [17], seems to be the major component for changes in mucus' rheology in PND. We therefore believe that therapeutic interventions focusing on better hydration or liquefaction of nasal secretions might have an improving effect on PND symptoms. Furthermore, normalized rheological properties of mucus during a symptom-free interval is consistent with recently reported analyses for sputum of subjects with cystic fibrosis [16]. The median values of nasal mucus viscosity in the present study are significantly lower than those of CRS patients found in the most recent report in literature, which used a cone-and-plate rheometer to analyze sinonasal mucus specimens [7]. This discrepancy may be explained by several reasons. Our analysis was performed using centrifuged Merocels for mucus collection enabling enough amounts of unprovoked nasal mucus collections also in healthy subjects. Thus, the fixation of more viscous components of nasal mucus on Merocels after centrifugation could be possible. However, as long as this effect occurred in healthy as well as PND subjects, the significant difference in viscosity in those groups should not be affected. In contrast, others just included individuals whose nasal examination revealed collections of mucus within the nasal cavities to enable a mucus collection by a suction attached to a specimen trap [7]. Furthermore, nasal mucus of their samples may be thickened due to long retention time in the nasal cavity. Our findings are not only novel but also unique in the way that even freshly produced anterior nasal secretions show significant differences in viscosity in PND subjects compared to healthy ones. Accordingly, the anterior part of the nose including the inferior nasal turbinate seems to be involved in PND's pathophysiology.

Own follow-up measurements of two PND patients during a symptom-free interval showed decreasing viscosity of nasal secretions, even within the range of control individuals. These findings support our hypothesis.

The reduced mucociliary clearance in PND patients may be caused by inflamed mucosa and increased viscosity of nasal secretions, as viscosity and mucociliary clearance negatively correlates with each other [7,8]. Due to the well-known fact of a delayed mucociliary clearance in smokers [18,19], smoking habits of all subjects were recorded. As all of our participants were non- or ex-smokers, smoking was no disturbing factor. The effect of a prolonged STT because of age [9] was eliminated by a matched control group. The influence of diabetes type 2 on a prolonged STT [9] was not detectable, since diabetes type 2 was occurring in both groups. Arterial hypertension [9] might be a disturbing factor, as it is only represented in the PND group. However, only two PND subjects were suffering from arterial hypertension.

As presented in Figure 4, nasopharyngeal sensitivity was reduced in 60% of PND patients. Rimmer and colleagues' study showed similar findings by demonstrating that patients with PND, unlike healthy subjects, cannot experience further increasing sensation after the insertion of either high or low concentrated HPMC in

saline in the nasal cavity to replicate postnasal drip [2]. PND patients were even unable to perceive a very thick mucus secretion in the form of the 4% HPMC [2]. In due consideration of assessed nasopharyngeal hyposensitivity in the current study, this might be derived from an altered sensory feedback caused by inflamed mucosa. Nevertheless, patients with PND often describe a sensation of fluid dripping or foreign body sensation in the throat, which could also be explained by a perceptual disturbance resulting from dysaesthesia. Another explanation may be, that postnasal drip secretion contains increased quantities of calcitonin gene related peptide and substance P, which are responsible for an altered sensation in the throat [20]. Consecutively, elevated levels of these mediators could cause increased cough sensitivity in some of these patients, as well.

Surprisingly, an inability to produce secretions in chronic rhinitics with PND symptoms has been described [21], which may also be explained by sensory dysfunction (hyperinnvervation/dysesthesia) rather than mucous hypersecretion as accounted for other reactive symptoms [22–24]. These findings go in line with ours, since the median volume of nasal secretions in PND and healthy subjects was 120 µl and 340 µl, respectively. Consistently, the concept of PND due to an increased volume of secretions moving from the posterior nasal choanae into the posterior nasopharynx/oropharynx seems to be questionable.

Our SPTs displayed atopy in 83.33% of all probands. Accordingly, neither the atopy nor the volume of nasal secretions appear to be largely relevant in PND symptoms, as they showed no significant differences in both groups.

Since a relevant part of PND patients reported increasing symptoms during stressful periods, a psychological component in pathophysiology may also be involved and should be further investigated.

However, based on our findings, viscosity seems to play a major role in the pathophysiology of PND as well as sensory dysfunction combined with prolonged mucociliary clearance. We believe these novel findings are of great importance going one step closer to understanding postnasal drip, as viscosity was found to be significantly increased in PND patients and decreasing in symptom-free intervals. Furthermore, this knowledge leads us to new therapeutic strategies such as the liquefaction of viscous nasal secretions in PND patients.

The present findings of this analysis should be interpreted within the context of its strengths and limitations. It was an attempt to describe the pathophysiology of PND more precisely in a prospective case-control study. It was – to the best of our knowledge – the first and only analysis of viscosity and volume of unprovoked collections of nasal secretion, mucociliary clearance and nasopharyngeal sensitivity in PND patients. Our study showed clear and consistent findings in tested individuals. Due to the nature of this observational study, it is not possible to establish a causative relation between nasal mucus rheological properties and PND severity or

treatment effects. As pharyngeal sensitivity seems to be altered, it is almost impossible to find such correlations. However, to substantiate our findings larger studies with follow-up examination – ideally in symptom-free episodes or at least in episodes with reduced symptoms – in all patients are mandatory. What remains unclear is whether treatments altering the viscous properties of nasal secretions would result in improved mucociliary clearance and, subsequently, clinical improvements in PND patients.

CONCLUSION

In conclusion, the viscosity seems to be a major component of the pathophysiology of PND, since PND subjects significantly showed higher values of viscosity in nasal secretions compared to controls. Follow-up measurements in symptom-free intervals confirm these findings. Additionally, hyposensitivity/dysesthesia and a delay in mucociliary clearance may play a role in the mechanism of PND, as well. Earlier concepts of PND due to an increased volume of secretions and atopy do not seem to hold true since our analyses showed no significant difference between cases and controls. Based on our own findings, we suggest including liquefaction of viscous nasal secretions in PND treatment algorithms. This may not only improve PND but also chronic cough symptoms and mucociliary clearance.

AUTHOR CONTRIBUTION

SB has planned and structured the study, recruited the patients, collected samples, has performed all laboratory analyses, has done the statistical testing, has written the manuscript and performed result analyses; PS has provided all skin prick tests and supervised their results, MBS has planned and supervised the study and drafted the manuscript.

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364 TABLES

Table 1: Demographic Information of Study Population

Characteristics	Postnasal Drip	Control	P-Value
Male / female (n = 30)	6 / 9 (40%/60%)	6 / 9 (40%/60%)	1.000
Mean age (years)	39.27 ± 14.5	38.47 ± 15.9	0.838
Sensitization / no sensitization	14 / 1 (93.33 %/6.67%)	11 / 4 (73.33%/26.67%)	0.367
Mean number of sensitization	4.07 ± 3.08	3.60 ± 3.16	0.683
Cough / No cough	7 / 8 (46.67%/53.33%)	0 / 15 (0%/100%)	0.004
CRS / no CRS	4 / 11 (26.67%/73.33%)	0 / 15 (0%/100%)	0.05
ARS / no ARS	2 / 13 (13.33%/86.67%)	0 / 15 (0%/100%)	0.189
Smoker / non-smoker	0 / 15 (0%/100%)	0 / 15 (0%/100%)	1.000
Mean number of medication	1.47 ± 1.41	0.93 ± 2.55	0.056
Mean number of comorbidities	1.67 ± 1.59	0.87 ± 1.30	0.089

365 Abbreviations: CRS = Chronic Rhinosinusitis, ARS = Recurrent Acute Rhinosinusitis

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FIGURE LEGEND

Figure 1: Significant difference in viscosity of nasal secretions at 1 rad/s between PND subjects and the controls ($p < 0.001$)

Figure 2: Significant difference in viscosity of nasal secretions at 100 rad/s between PND subjects and the controls ($p < 0.001$)

Figure 3: Significant difference in mucociliary clearance between PND patients and the controls ($p = 0.008$)

Figure 4: Significant difference in sensitivity between PND patients and the controls ($p = 0.002$)

Figure 5: Sensitivity measuring instrument PND

Table 1: Demographic Information of Study Population

Characteristics	Postnasal Drip	Control	P-Value
Male / female (n = 30)	6 / 9 (40%/60%)	6 / 9 (40%/60%)	1.000
Mean age (years)	39.27 ± 14.5	38.47 ± 15.9	0.838
Sensitization / no sensitization	14 / 1 (93.33 %/6.67%)	11 / 4 (73.33%/26.67%)	0.367
Mean number of sensitization	4.07 ± 3.08	3.60 ± 3.16	0.683
Cough / No cough	7 / 8 (46.67%/53.33%)	0 / 15 (0%/100%)	0.004
CRS / no CRS	4 / 11 (26.67%/73.33%)	0 / 15 (0%/100%)	0.05
ARS / no ARS	2 / 13 (13.33%/86.67%)	0 / 15 (0%/100%)	0.189
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Abbreviations: CRS = Chronic Rhinosinusitis, ARS = Recurrent Acute Rhinosinusitis